An Attempt to Measure the Volume of a Tree-trunk

Test Report

by

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1 Introduction

1.1 Aims and Objectives

The Aim of this exercise is to learn and test the *ArchiCADv20 , Rhino3Dv5/Grasshopper v.09.0076* software in order to be able to model objects and obtain various data such as

- Surface Areas and
- Volumes of a model.

The Rhino (RH) is directly linked to Grasshopper (GH) software, the ArchiCAD (AC) is linked to this real-time collaboration of software occasionally. The RH is a freeform 3D modeler software (McNeel-Europe-SL 2016), the GH is a graphical-algorithm editor issued by the same software manufacturer. The ArchiCAD is a CAD software used predominantly by architects.

2 Test – 1 Modelling simple objects

2.1 Cylinder

The volume of a simple cylinder with the Radius = 1.0 m and Height=1.0 m should equal with the numeric value of “ π.” =3.141592. The cylinder can be decomposed to 2 circles and surface between the circles. The values of the Radius and the Height can be interactively modified with the use of the Numeric Slider (Figure 1).

Figure 1 Modelling a Cylinder with Rhino (RH) and Grasshopper (GH)

The surface between the bottom and the top surfaces (bases) is created with the GH *Ruled Surface* tool. The GH *Cap Holes* tool creates the bottom and the top surfaces of a cylinder. The yellow stickers (Panels) are displaying the numeric values of the cylinder (Figure 2).

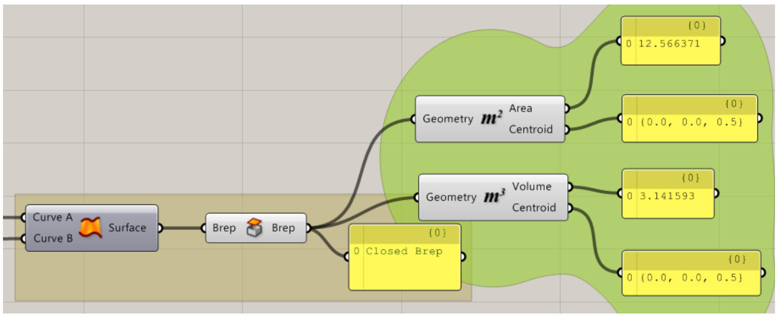

Figure 2 Create a cylinder with Ruled Surface and Cap Holes tools in Grasshopper (GH)

Several other tools were tested with the same input data. The use of the Patch Surface tool however resulted a slightly different Volume value than expected (Figure 3)! Further investigation is required to explore the capabilities and the limitations of the surface creating tools.

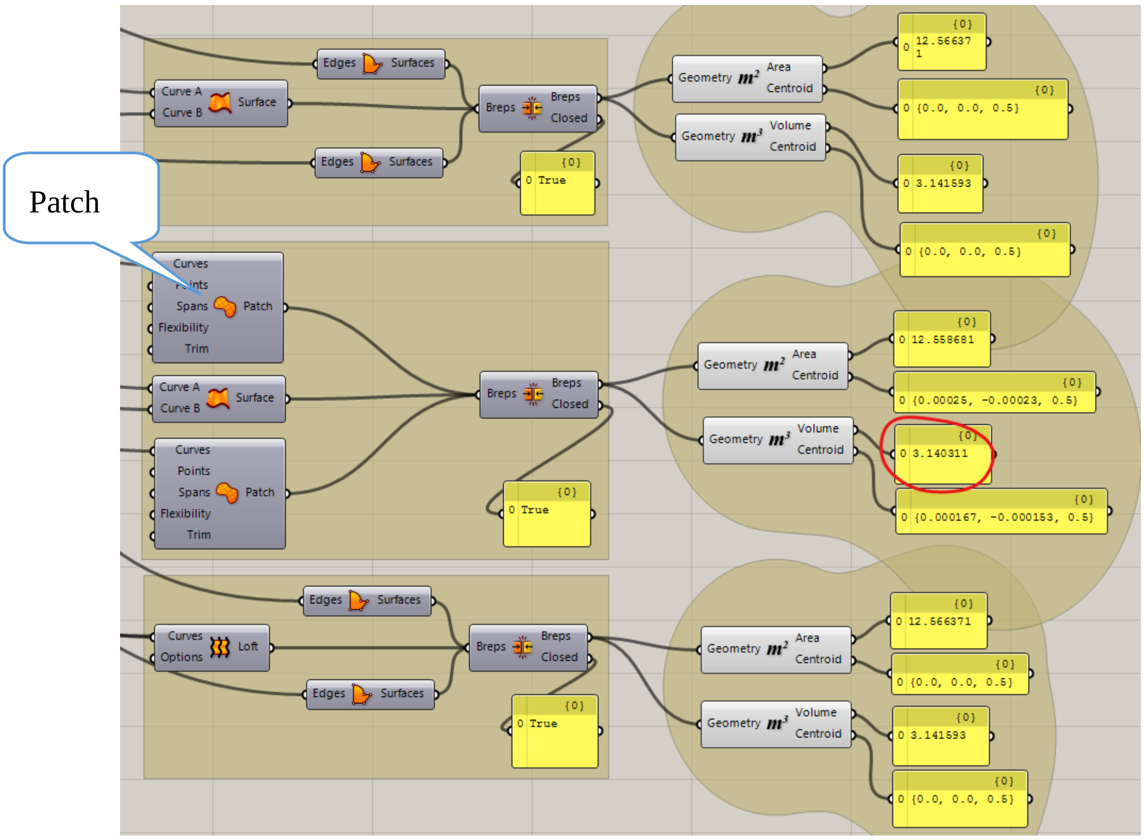

Figure 3 Various Surface tools were tested. The outlier values are marked with red.

3 Test 2 - Real World Data of a Tree Trunk

This test uses 'real wold information'; a point cloud data of an existing tree. The file was obtained from UTAS.

3.1 Pre-Processing the data with LAStools

The "Specimen Tree" point cloud (UTAS 2015) contains over 3 million points in LAS1.2 file format. As it is shown in the LASVIEW window (Isenburg 2014), the longitudinal centre line of the tree is following the X axis. The file contains over 3 million points (Figure 4) organised in a Cartesian coordinate system using an arbitrary local origin established by the photogrammetry software Agisoft PhotoScan.

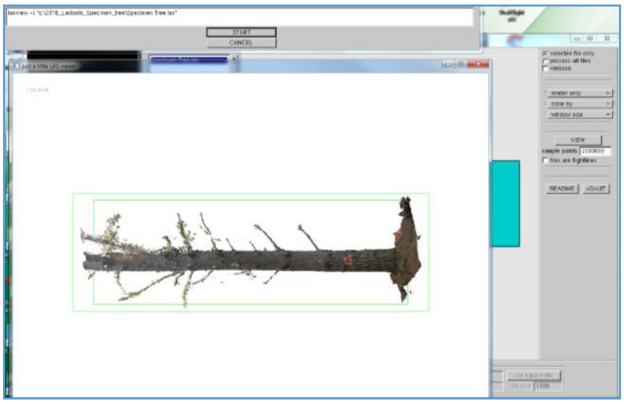

Figure 4 The "Specimen" LAS file in LASVIEW

In order to obtain the perimeter of the trunk, the file of the tree was "sliced" twice, approximately 1 m apart (Figure 5) with the help of LAStools GUI.

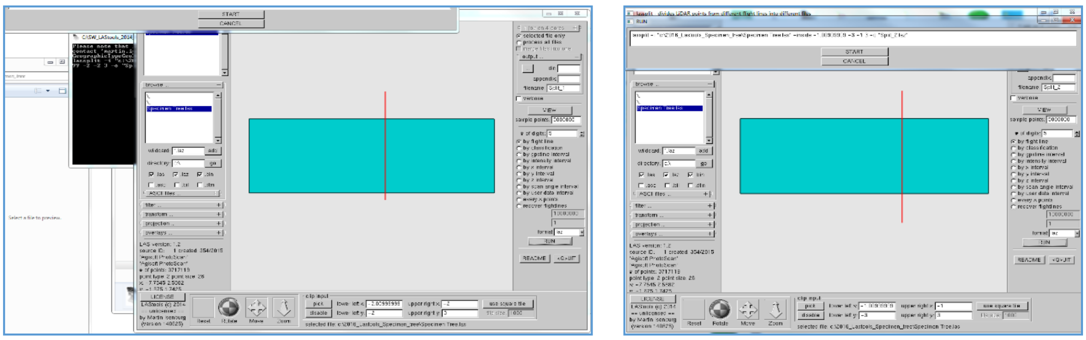

Figure 5 "Split" no1 and "Split" no2 (Lasview screen capture)

The height and the depth of the ring shaped point cloud is about 2mm (Figure 6). The average Euclidean distance between the points is about 3 mm, from min. 1 to max. 12 mm.

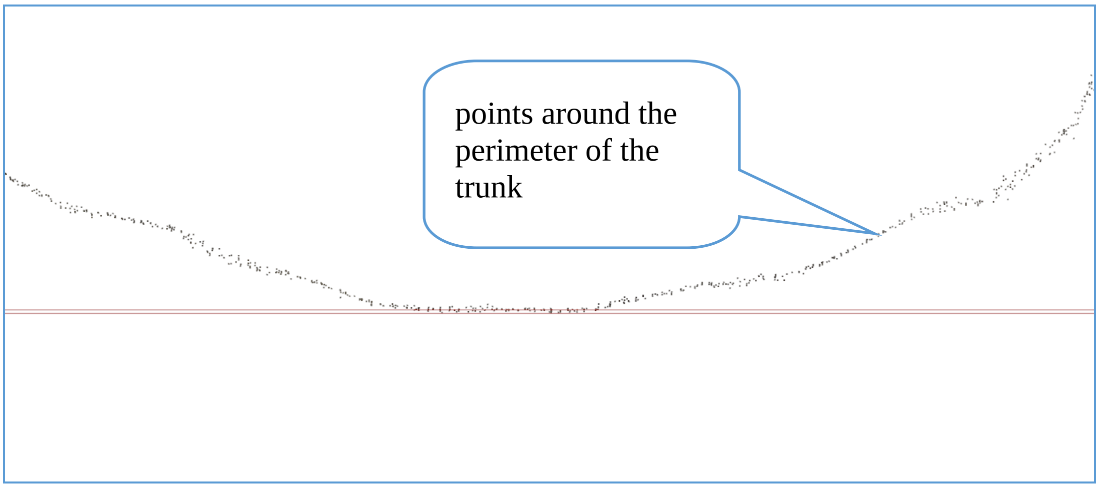

Figure 6: The distance between the red lines is 1 mm (Lasview screen capture)

According to the LASinfo tool report, the “Split-1” contains 3434 points, the “Split-2” contains 3572 points, which indicates that the density of the scattered points of the slices are similar. The outlier points, the “branches of the tree”, were deleted (Figure 7).

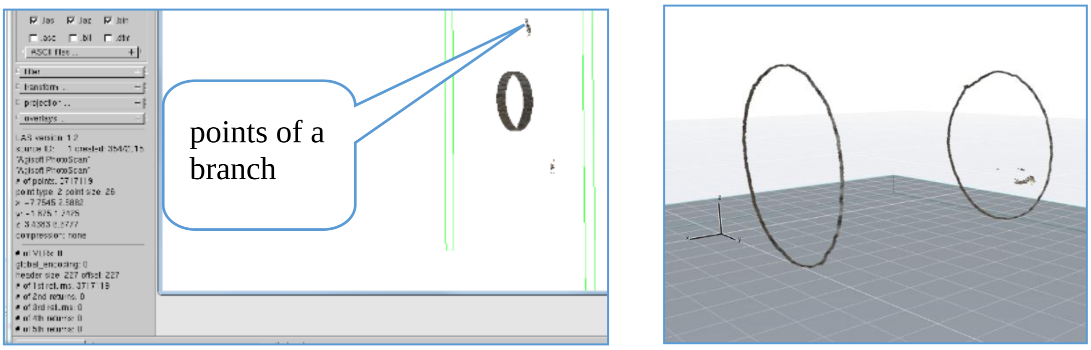

Figure 7 Left: The “Split-1” in LASVIEW Right: The 3D view of the “Split1” and “Split-2” in the CAD software

The available software combination of the *ArchiCADv20 , Rhino3Dv5/Grasshopper v.09.0076* was not designed to interpret point cloud in LAS file format, therefore “Split-1” and “Split-2” files were translated to an ASCII-text file with the Las2txt tool.

3.1.1 Initial investigation

Using only the CAD software, the points of the "Split-1" were digitised manually into a "spline". The area of the closed spline: 0.3005 square metre. (Figure 8).

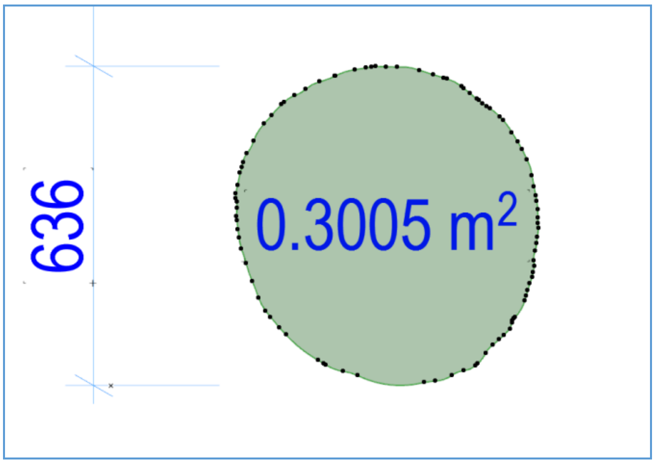

Figure 8 The "Spline" and the "Fill" in a CAD system

As a next step the "Fill" was horizontally extruded. The distance of the extrusion in this particular case was set to 1000mm, which equals with the distance between the "Split-1" and "Split-2" (Figure 9).

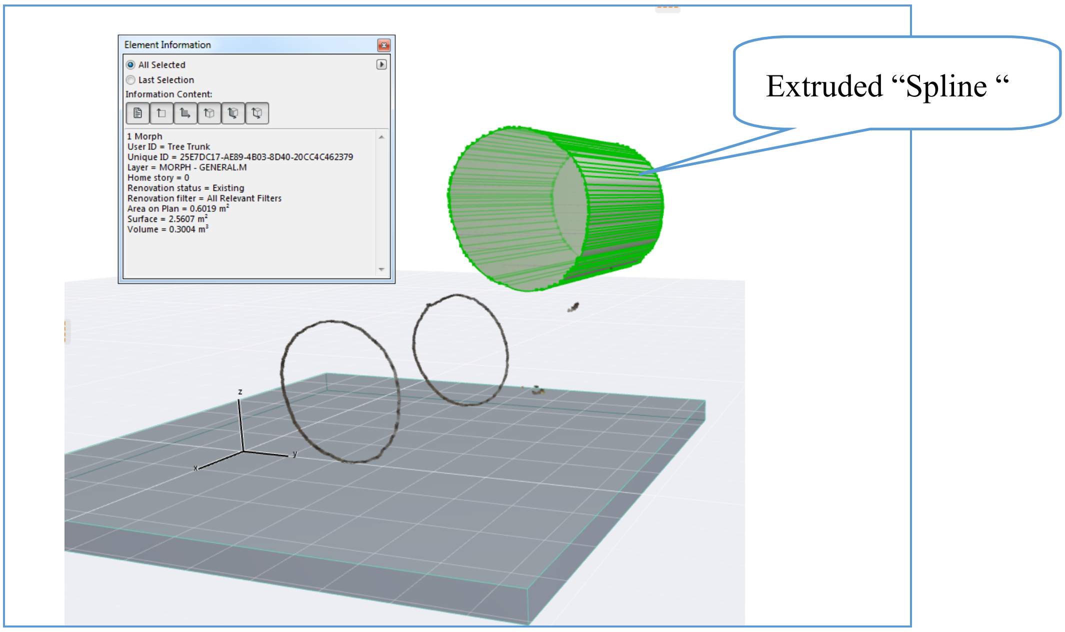

Figure 9 The "Split-1", the "Split-2" and the extruded "Fill"

The Element Information pop-up menu of the CAD software automatically lists the basic geometrical information of the 3D object. Please note that a non-uniform object, such as the extruded “Fill” at *Figure 9* is called as “Morph”, which is a technical term to indicate that this 3D object was created with the use of the “Morph” toolset. The “Area on Plan” value indicates the “horizontal footprint” parallel with the white gridline on the grey surface on *Figure 9*.

Please also note that the cross-section of the Morph object on *Figure 9* is uniform and matches only with the “Split-1” cross section. The cross-sections of “Split-1” and “Split-2” however are slightly different. The Volume value of the Morph therefore just indicates the volume of the (1 m length) tree-trunk; it can be used as a rough estimate only.

The aim is to try to model a trunk-object, where the start and the end cross sections are different. For this purpose, the *Rhino3D-v5* (RH) and the *Grasshopper v.09.0076* (GH) software were employed. The RH is a freeform 3D modeler software (McNeel-Europe-SL 2016), the GH is a graphical-algorithm editor issued by the same software manufacturer.

3.2 Pre-Processing the “Slice-1” and “Slice-2” point cloud data in RH/GH

3.2.1 Brief introduction of RH/GH

The “Rhicoceros-3D” or “Rhino” (RH) is a 3 D modeler software. Its workspace on the screen is usually separated into 4 viewports, the “Top”, “Front”, “Right” and “Perspective”, consequently the 3D model can be observed from the top, from two sides and in a perspective projection at the same time (Figure 10).

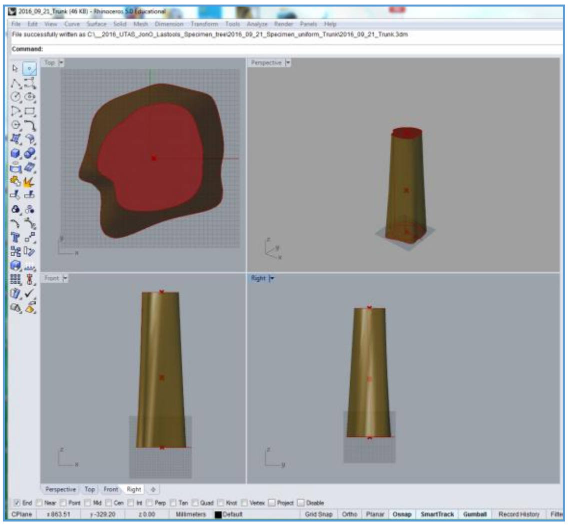

Figure 10 “Rhino (RH) viewports

The GH workspace, the "canvas" is a separate window from the RH. The GH represents the data and the interactions between data with various icons and lines, which link the icons into a network (Figure 11).

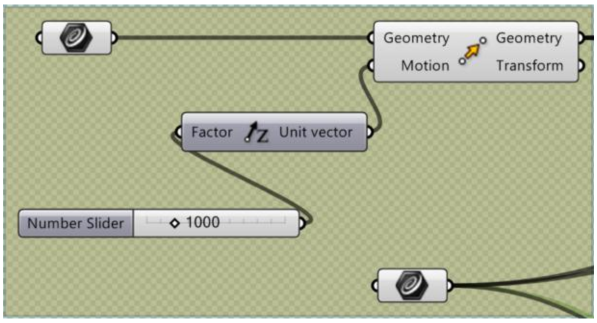

Figure 11 The "canvas" of the Grasshopper (GH)

All settings, adjustments, changes or actions on the "canvas" are immediately visualised in the viewports of the RH. The two software are fully integrated. RH supports the real-time collaboration of software; consequently, more than one software can be linked together into a network of a working-team. During this test, time to time the ArchiCAD (AC) software was also plugged-in to the RH/GH work-team.

3.2.2 Import data

The icons marked with "C:/"  are set to read the path of the text file in order to open and import it to the RH/GH workspaces (Figure 12). The icon marked with "XYZ" selects the X, Y, and Z values from the TXT file and converts them into a point cloud within the active software group environment.

The data flow or stream (always from left-to-right) is indicated with black lines. The double black line indicates the stream of multiple data. The yellow stickers produce the vital information about the data and the actions (Figure 12). In this particular case the point cloud was rotated around the X-axis of the local reference frame; in order to position the "Slice-1" and the "Slice-2" cross section perimeter points on the top of each other along the Z-axis (Figure 12).

> Note: In the Specimen Tree.LAS file the longitudinal shape of the tree-trunk was laying parallel with the X-axis (Figure 4). That is why the rotation of the "Slices" was required.

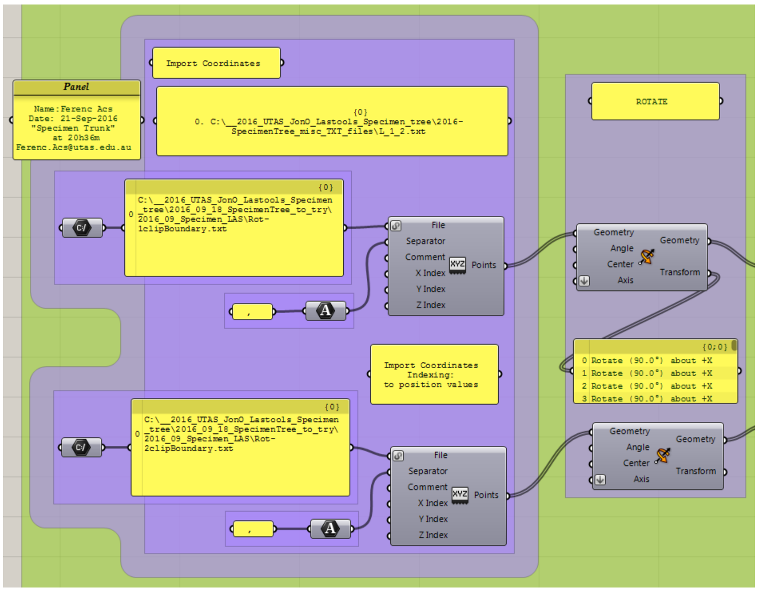

Figure 12 Detail of the algorithmic flowchart of RH;
Import and Rotate "Slice-1" and "Slice-2" point cloud files

At this stage the points of "Slice-1" and "Slice-2" form two approximately 2 mm high (vertical) and 2 mm deep (XY plane) "rings". These rings are representing the perimeter of the tree trunk in the RH viewports. The height of the slice was on purpose set to 2 mm. in order to gather more detailed information about the shape of the perimeter. In this way each ring contains slightly more than 3000 scattered points around an approximately 600 mm diameter trunk.

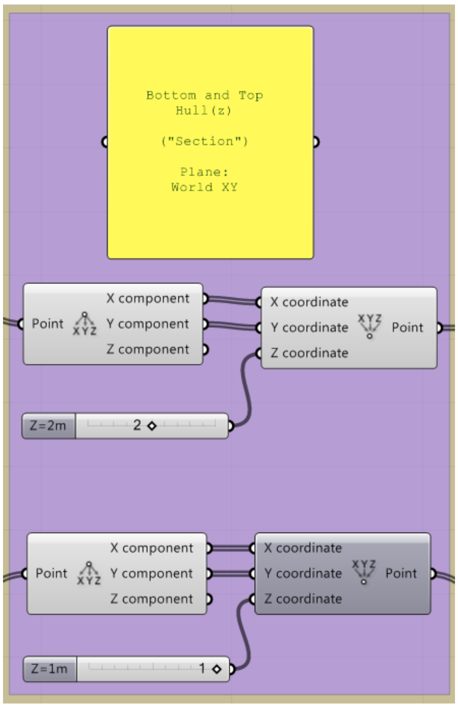

Figure 13 Horizontal adjustment (appr. 2 mm)

The next step is to normalise the Z-component of the points of the "Slices" to eliminate the vertical scattering of the points in the "Slices". This action introduces a certain distortion into the point cloud with the approximate magnitude of 2 mm along the Z axis. As a result, the points within a "Slice" possess the same Z value, and the two "Slices" are exactly 1000 mm apart (Figure 13).

3.2.3 Creating Polyline Perimeter curve around the trunk

As a next step the points surrounding the trunk (perimeter) were digitised into a polyline. The points of the “rings” were approximately 2 mm deep (XY plane). It was assumed that there were no outlier points within the “ring”, therefore the GH “Convex Hull” tool was used to create the polyline automatically. The range of the Euclidean distance between the scattered points was between 1 and 8 mm and most of the points were approximately 2 mm apart. The average depth (XY plane) of the “Slice” was also about 2 mm, therefore the segments of the polyline zigzagged, which created a situation where the computer hardware may have been overpowered.

As a solution new points were distributed along the polylines at every 10 mm. These points were used to create two new, a bit smoother polylines (“Slices”).

Note: The parametric nature of GH/RH allows direct control over the parameters. The distribution of the newly introduced points can be freely and interactively modified with the use of the Number-Slider (Figure 14).

The results of the smoothing procedure were visually monitored. It was assumed that the visual control over this process is sufficient at this stage of the project.

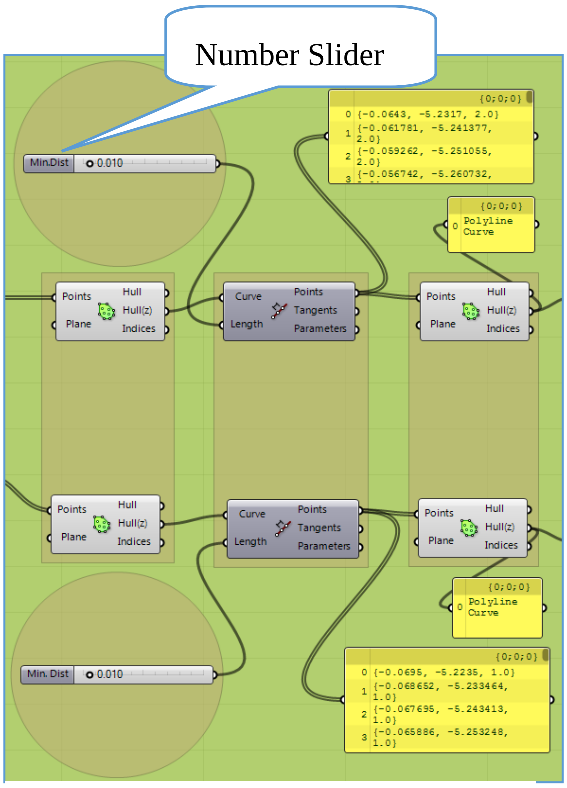

Figure 14 The “Convex Hulls” are interactively adjusted with the use of the Number Slider

With the help of the yellow stickers (Panels) however the exact XYZ position of the points can be extracted instantaneously, at any stages, for further mathematical investigation.

3.2.4 Creating Surfaces

Initially the Specimen Tree was modelled with the help of a dense points cloud of scattered points (LAS file).

In this version of the test, the trunk is modelled with surfaces. The top and the bottom of the trunk is described by the polylines, created previously from the "Slice-1" and "Slice-2" point cloud. The top and the bottom are smooth, flat surfaces with uneven, undulating boundaries. The vertical surface, which is created between the "Slices" is also uneven and undulating due to the geometrical differences between the polylines.

> Note: It is assumed that if the "Slices" are adequately close to each other, then the shape, therefore the volume of the trunk pieces could be sufficiently estimated. In this test however the distance between the "Slices" are set to 1000 mm. With the 1 m height it was easier to manually check the volumes of the mock-up models, which were constructed to assess the algorithmic test model.

- The top and the bottom surfaces were created with the use of the GH *Boundary Surfaces* tool.
- The surface between the "slices" was created with the GH "*Ruled Surface*" tool.
- The three surfaces were joined with the GH *"Brep Join"* tool.

The model of the trunk therefore is represented by infinite thin (Boundary Representation or Brep) surfaces. Certain values, such as

- Centroid,
- Area or
- Volume

can be directly monitored or extracted on the fly using the yellow stickers (Panels) on the GH canvas (Figure 15).

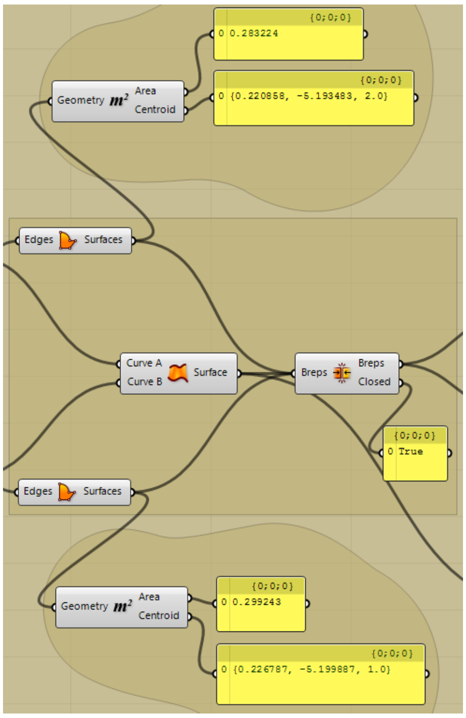

Figure 15 Creating Surfaces

The Brep surface model of the Trunk in RH viewports (Figure 16 and Figure 17).

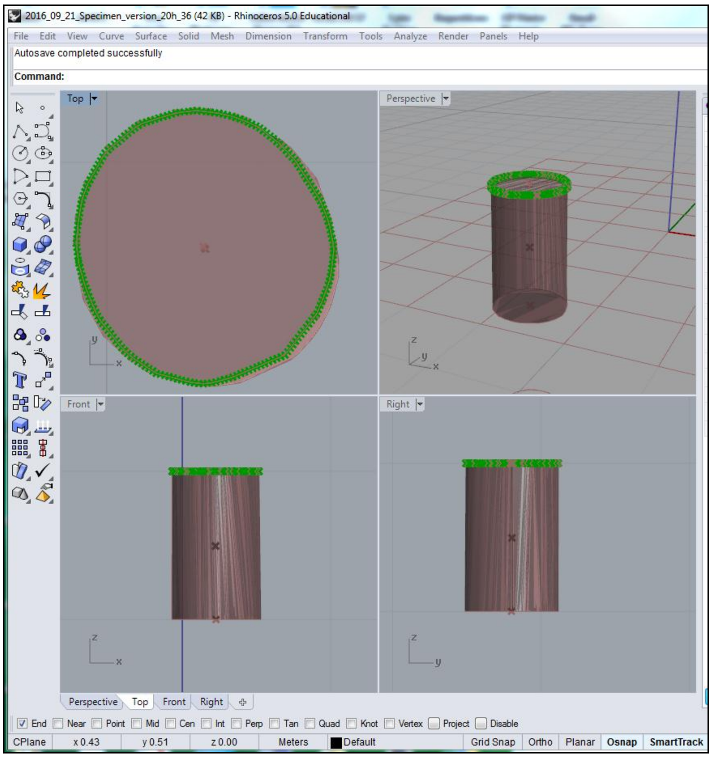

Figure 16 The Trunk in RH viewports The green dots are the evenly distributed (new) points on the perimeter polyline

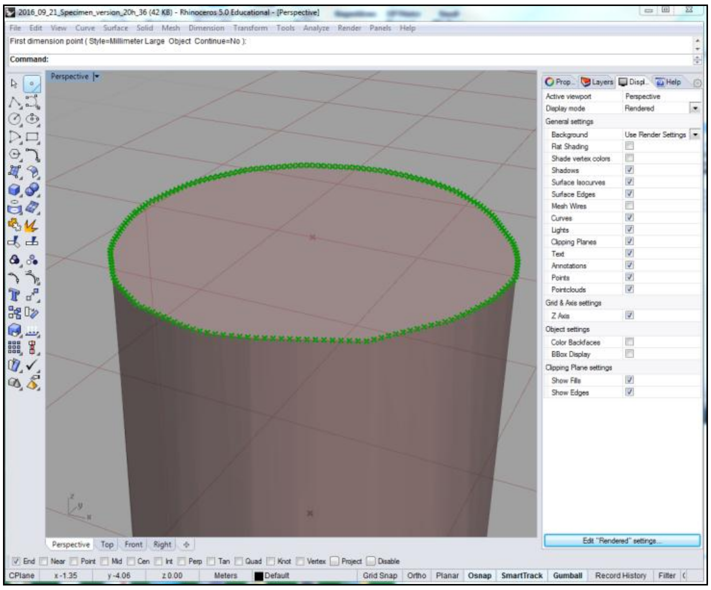

Figure 17 The Trunk in RH Perspective viewport. The green dots are the evenly (new) distributed points on the perimeter polyline

During this test the Rhino, the Grasshopper and the ArchiCAD software were linked directly to each other, sharing the same hardware and screen. This real-time collaboration capability is a standard feature of these software. The direct link can be activated and de-activated with a single command.

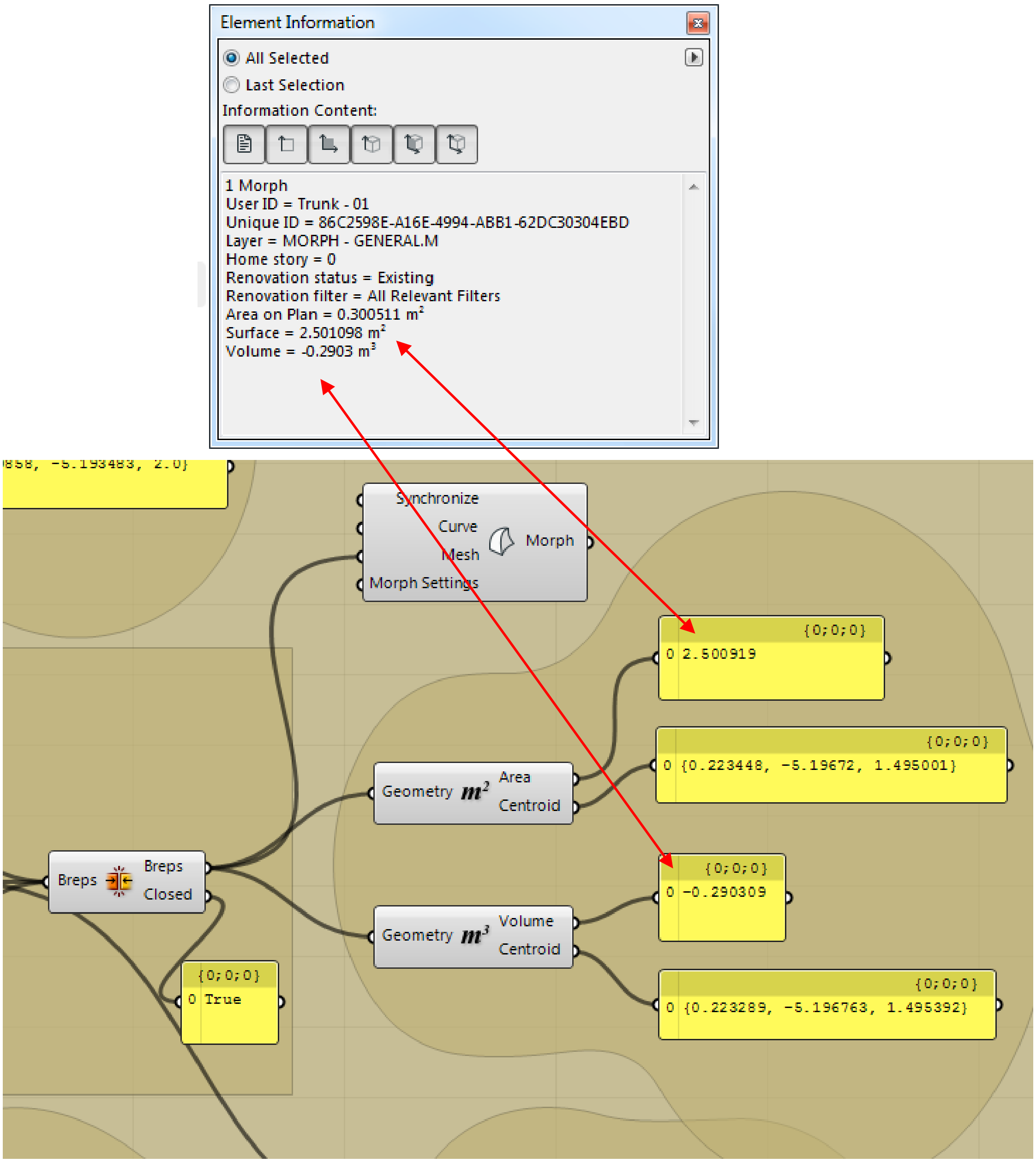

Figure 18 Results in AC (Element Information above) and GH (yellow stickers)

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Last edited: 22-09-2016

4 Glossary

5 Bibliography

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6 Table of Figures